Automotive Engines for the 1980's

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The reciprocating piston engine has dominated the automotive scene for more than 60 years and until very recently, at least to most realists, seemed unlikely to ever be displaced. Although the piston engine has served its users well for many years and is likely to continue to do so for some time to come, it does have a number of shortcomings which are becoming more serious as ever greater numbers come into use and as we become enlightened on social values. It is a major contributor to air and noise pollution. It is also relatively inefficient and has a narrow fuel tolerance consuming large amounts of highly refined petroleum.

The early phases of an expected long-term energy crisis are now upon us. The era of abundant low cost energy is over. Much higher prices are certain and rationing likely cannot be avoided. The need to greatly increase efficiency rather than trade off efficiency for emission control is therefore becoming more obvious. Before the end of this century (which is closer than the end of World War II) petroleum must likely be replaced as the dominant fuel for mobile powerplants.

Although much progress has been made in reducing automotive emissions, it has been achieved at the price of increased fuel consumption. Much further reductions in emissions are needed to meet the requirements of the Clean Air Act of 1970. Growing, but of somewhat lesser importance is the issue of noise pollution.

Wankel, Stirling, turbine, stratified charge and diesel engines are the most serious contenders to replace or supplement today's piston engines. Electric vehicles are not considered serious contenders because of grossly inadequate technology and steam engines have too low an efficiency.

In addition to the three social parameters discussed previously, there are seven other major engine selection parameters - flexibility (torque-speed characteristics and driveability), smoothness, cost, weight, size, maintenance requirements and durability. Figure 1 lists these parameters in order of importance for passenger cars as of 1973. Arrows show the importance of noise and especially, fuel consumption rising to late 1970's (and perhaps Mid-1970's) values. The five contenders are compared on these ten parameters with the 4-cycle gasoline piston engine.

The Wankel, despite much recent fanfare, has little to offer in the three important social areas and uses substantially more fuel. It

is also a more costly and less flexible engine and has poorer durability characteristics.

The Wankel is smaller and lighter, but nowhere near as much as often claimed. These advantages are not readily convertible into major reductions in vehicle size and weight. Design studies indicate that several of the most compact cars using transverse piston engines would have to increase in length if a Wankel engine were substituted.

The turbine engine is quieter and can have very low emission but has higher fuel consumption. It is lighter, smoother and more flexible, should require less maintenance, but is costly and its durability has not been proven (automotive application). The turbine requires considerable additional development before it could enter volume production.

The Stirling engine has the lowest fuel consumption, lowest emissions, and the lowest noise of any known engine. It is potentially capable of burning any fuel since it is an external combustion engine. It is becoming increasingly apparent that we must supplement or begin to replace petroleum consuming mobile powerplants within the next 10 to 20 years. The Stirling engine also has flexibility, smoothness, maintenance and durability advantages, but tends to be somewhat bulky and costly.

The Stirling engine is in an early state of development. Introduction in high volume production is not likely until at least the early to Mid-1980's.

Stratified charge engines could be introduced relatively quickly into production as it is a variation of today's piston engine. The stratified charge engine provides a better trade off between fuel consumption and exhaust emissions; the engine appears to be capable of meeting the interim 1975 and 1976 emissions standards while equalling or bettering today's engines' fuel economy.

Stratified charge engines have a disadvantage in that their specific power output is somewhat less than conventional engines, resulting in lower performance cars or an increase in engine size. Ultimately this disadvantage may be overcome by turbocharging but at least the first generation of stratified charge engines are not likely to use turbochargers.

Diesel engines have low fuel consumption and low emissions of controlled pollutants but high emission of smoke,odor and noise. They require less maintenance and have a long life but are at a disadvantage in all other characteristics.

On balance therefore, the stratified charge reciprocating engine appears to be the leading near-term challenger and the Stirling engine, the leading long-term contender.

Figure 2 is a composite chart showing our estimated range of probable market penetration of each engine type through 1985. The lower dark shaded band is for the Wankel. The maximum probable is about 13% by 1980 and 23% by 1985. The minimum probable rises to 3% in the late 1970's gradually fading away in the early-1980's. Second, for the turbine and Stirling engines - penetration again, from none up to 8%. The balance of the market, the reciprocating piston engine is obtained by subtracting the sum of turbine and Wankel minimum and maximum penetrations from 100. It would have a market share of at least 69% and could conceivably take the whole market in 1985. The maximum piston engine market share in 1980 is 97% due to the forecast minimum Wankel penetration. The number of catalyst-controlled reciprocating engines will be substantially lower than shown if the 1975 standards are liberalized. The picture for 1976 and beyond is still very unsettled.

The catalyst curve shows an early decline as the stratified charge engine comes into use. The stratified charge engine may indeed prove sufficiently attractive to not only take over this whole reciprocating engine segment, at least 69% of the total, but to even recapture the small segment lost to the Wankel in the mid- and late-1970's. By 1985 the stratified charge engine could be the only engine in production.

In conclusion:

1. Reciprocating piston engines will remain dominant well into the 1980's.

2. Vehicle and engine manufacturers continue to approach change with caution and will follow conservative introduction and commercialization strategies.

3. Economics will continue to be the dominant influencing factor.

4. But social requirements, especially fuel consumption, will become more significant in influencing change to different engines.

The overall conclusion, therefore, is that there still is considerable uncertainty as to the choice and rate of commercialization of specific <u>new</u> engines, but no revolutions are likely in the near future.

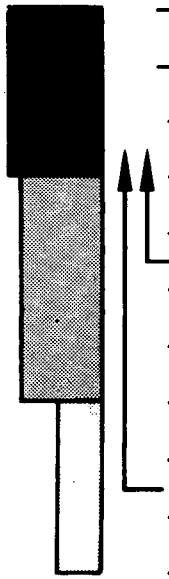
This summary is based on a complete report by the same title published by the Eaton Corporation.

Major inputs for the report were obtained from over 60 in-depth interviews worldwide. These included car and truck manufacturers; heavy duty and small engine producers; developers of new engines; materials, parts, fuels and lubricants suppliers; machine tool builders; government agencies; trade associations; independent research institutes and consultants. These inputs were combined with business, technical and historical analyses and an evaluation of the social, political and economic forces that cause change.

Primary emphasis was placed on the Wankel engine and on those factors which will have the greatest bearing on its (degree and rate of) commercialization. Priority was placed on passenger car application followed closely by heavy duty markets with a relatively modest effort in the small engine area.

Relative Importance of Selection Parameter

Passenger Cars — Compared with 4-Cycle Spark Ignition Piston Engine



	Wankel	*Turbine	Stirling	Stratified Charge	Diesel
Flexibility	–	+	+	0	–
Smoothness	+	++	++	0	–
Emissions	0	+	++	+	+
Cost	–	–	–	?	–
Noise	0	+	++	0	–
Weight	+	+	0	–	–
Size	+	0	–	–	–
Maintenance	0	+	+	0	+
Fuel Consumption	–	–	++	+	++
Durability	–	?	+	0	+

Advantage (+) or Disadvantage (–) *Two-Shaft Regenerative 1900 F Turbine Inlet Temperature

FIGURE 1

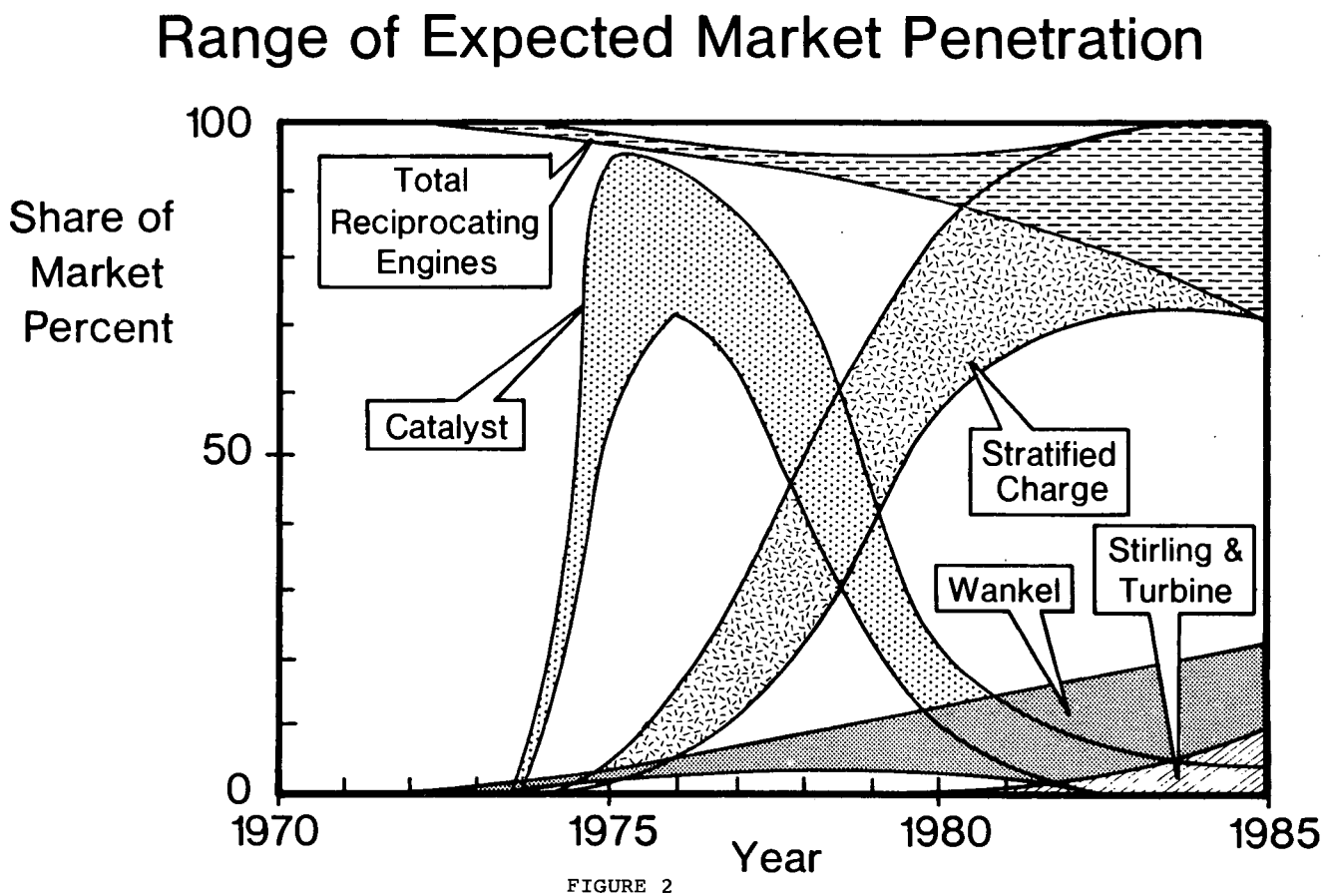

Range of Expected Market Penetration
Share of Market Percent
100
50
0
1970
1975
1980
1985
Year
Total Reciprocating Engines
Catalyst
Stratified Charge
Wankel
Stirling & Turbine

FIGURE 2